Melengestrol Acetate in Experimental Diets as an Effective Alternative to Induce a Decline in Egg Production and Reversible Regression of the Reproductive Tract in Laying Hens I. Determining an Effective Concentration of Melengestrol Acetate

J. M. Koch,* J. S. Moritz,* D. C. Lay Jr.,† and M. E. Wilson*,[1]

*Division of Animal and Veterinary Science, Davis College of Agriculture, Forestry and Consumer Sciences, West Virginia University Morgantown, West Virginia 26506; and †USDA-ARS Livestock Behavior Research Unit, Purdue University, West Lafayette, Indiana 47907

ABSTRACT Induced molting increases egg quality and egg production and extends the productive life of hens. Molting is accomplished by feed withdrawal, which has been criticized for not addressing hen well-being, and current alternatives have resulted in poor postmolt performance and inadequate well-being. Molting leads to regression of follicles on the ovary and causes loss of steroidogenic support for the oviduct, leading to cessation of lay. Melengestrol acetate (MGA), an orally active progestin, may decrease support for the ovary, resulting in loss of support for the oviduct, while hens are fed a balanced diet. In this experiment, a dose response study, Hy-Line W-36 hens were fed 0, 0.1, 1, 4, or 8 mg of MGA per hen/d in a balanced diet for 28 d and then returned to a normal diet. Four birds on d 0 and 4 birds per treatment on d 1, 2, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, and 44 were euthanized. The weight of the ovary with follicles, magnum, shell gland, and oviduct were determined. A decrease in egg production was observed in those groups receiving 4 and 8 mg of MGA, until removal of MGA from the diet. After d 28, egg production increased to the production level of hens fed 0, 0.1, or 1 mg of MGA. The weight of the ovary with follicles, oviduct, magnum, and shell gland were unchanged throughout in groups fed 0, 0.1, or 1 mg of MGA. However, groups fed 4 or 8 mg of MGA exhibited a decrease ($P < 0.05$) in the weight of the ovary with follicles, oviduct, magnum, and shell gland until d 28. Recrudescence of the large yellow follicles as well as rejuvenation of the oviduct and its components, the magnum and shell gland, in the 4 and 8 mg MGA groups occurred by d 44. Melengestrol acetate, fed to hens on a balanced layer diet, caused reversible regression of follicles and, therefore, removal and return of support for the oviduct.

(*Key words*: chicken, molting, melengestrol acetate, well-being)

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INTRODUCTION

Laying hens are induced to molt to increase egg quality and egg production and extend the productive life of the hen. The predominant management practice to induce a molt requires an extended period of feed withdrawal, often accompanied by reduced lighting and limited water access. Molting induced by feed withdrawal has received public criticism concerning the well-being of the hen, leading the United Egg Producers and others (i.e., McDonalds corporation, which purchases over 1.5 billon eggs/yr) to explore acceptable alternatives (Gast and Ricket, 2003). Current alternatives to molting induced by feed withdrawal include feeding diets with altered mineral composition (i.e., low sodium, low calcium, or high zinc) or low nutrient density (i.e., high wheat middling inclusion) that do not provide the daily nutrient requirements of the hen (Berry, 2003). These alternatives do not reliably improve postmolt egg quality and in some cases have caused dehydration, paralysis of the hen, and liver, kidney, and adrenal gland damage, resulting in increased mortality (Siegel, 1961; Lumijarvi et al., 1966; Douglas et al., 1972; Berry, 2003).

An alternative to molt induced by feed withdrawal is needed that addresses hen well-being, postmolt performance, and practical application. Injecting progesterone into hens has been shown to cause a cessation of lay within 10 d (Gabuten and Shaffner, 1954; Shaffner, 1954;

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[1]To whom correspondence should be addressed: mwilso25@wvu.edu.

Abbreviation Key: FSH = follicle-stimulating hormone; GnRH = gonadotropin-releasing hormone; LH = luteinizing hormone; MGA = melengesterol acetate.

Table 1. Preliminary data for testing carriers for melengestrol acetate

	Hen weight (kg)		Egg production (n/week)		Egg weight (g)	
Diet additive	Wk 1	Wk 2	Wk 1	Wk 2	Wk 1	Wk 2
33% soybean hulls (n = 16)	1.64 ± 0.06	1.17 ± 0.05	33	36	69.1 ± 1	69 ± 1
13.5% propylene glycol (n = 16)	1.79 ± 0.05	1.80 ± 0.05	35	44	70 ± 1	70 ± 2

Adams, 1956). However, a practical method would have to be easily administered to thousands of hens simultaneously, such as the use of an orally active progestin. Such an approach would allow hens to be maintained on a balanced layer diet that meets daily nutrient requirements, thus addressing hen well-being and potentially decreasing morbidity and mortality while effectively inducing a molt. Therefore, the objective of this experiment was to determine a dosage of an orally active progestin, melengestrol acetate (MGA) that would downregulate the hypothalamic-pituitary-ovarian axis leading to reversible regression of the large yellow follicles and the oviduct, causing a temporary reduction in egg production.

MATERIALS AND METHODS

Preliminary Studies

A preliminary experiment was conducted to determine which carrier of MGA, either soybean hulls (440 mg of MGA/kg) or propylene glycol (1,100 mg of MGA/kg), would be more palatable, and if a hen could consume enough carrier in 1 d to meet the maximum dosage (8 mg/d) proposed for the subsequent experiments. These 2 carriers are the only commercially available formulations of MGA, and both were used in the preliminary experiment to pick the most appropriate carrier based on dosage and palatability. To determine the appropriate carrier, 32 hens were divided into 2 groups and fed a diet containing 33% soybean hulls or 13.5% propylene glycol. Hen weight, egg production, and egg weight were determined for 1 wk prior to the start of the preliminary study when hens were fed a standard layer ration (Table 1). During the second week of the preliminary experiment hens were fed diets containing soybean hulls or propylene glycol, and hen weight, egg production, and egg weight were determined (Table 1). The preliminary experiment demonstrated that hens would consume both carriers. Propylene glycol was used in the subsequent experiment because of its smaller required inclusion rate to facilitate formulating a balanced layer diet. To properly formulate a balanced layer diet, the metabolizable energy of propylene glycol for laying hens needed to be determined. Therefore, hens (n = 5) were placed in individual metabolism cages and acclimated for 2 wk before being placed on a diet containing 30.0% propylene glycol, 57.7% ground corn, 9.00% limestone, 3.00% defluorniated phosphate, 0.25% vitamin and mineral premix, and 0.09% sodium chloride. Hens were fed the diet for 3 d during which time feed intake and the mass of excreta were recorded. The energy content of feed and excreta were determined via bomb calorimetery (Parr 1266 bomb calorimeter, Preiser Scientific Inc., Moline, IL). The experimental estimate for metabolizable energy of propylene glycol was 3,454 kcal/kg using 3,350 kcal/kg for the metabolizable energy of corn (NRC, 1994). In order for a hen to receive 8 mg of MGA (International Nutrition, Omaha, NE) per day (based on 100 g of intake/d) diets were formulated to contain 7.27% propylene glycol (Table 2). Melengestrol acetate is approved by the FDA to be fed to heifers to suppress estrus but has not been approved for use in chickens.

Experiment

Hy-Line W-36 laying hens (n = 264) at 40 wk of age were used for the experiment. All hens were housed 3 per cage with 186 cm^2 of floor space per bird and exposed to 18 h of light per day. Birds were fed a corn and soybean meal based diet that was balanced to meet NRC requirements (Table 2; NRC 1994); birds were provided ad libitum access to water for 18 wk before the start of the experiment. Eggs were collected and counted daily. All procedures involving animals were approved by the West Virginia University Animal Care and Use Committee (no. 02-1203).

Table 2. Composition of the experimental and control diets

Component	Experimental diet	Control diet
Corn (%)	48.12	57.62
Soybean (%)	27.00	27.00
Limestone	9.20	9.14
Propylene glycol (%)	7.27	—
Fat (soy oil; %)	3.16	2.79
Corn gluten meal	2.72	1.50
Defluorniated phosphate (%)	1.92	1.39
Vitamin and mineral premix (%)[1]	0.25	0.25
Sodium chloride (%)	0.20	0.21
Methionine (%)	0.17	0.10
Calculated composition		
ME (kcal/kg)	2,882.0	2,882.0
Crude protein (%)	17.38	17.38
Methionine (%)	0.45	0.45
Lysine (%)	0.87	0.87
Calcium (%)	4.20	4.20
Available phosphorus (%)	0.46	0.46

[1]Supplied per kilogram of diet: manganese, 0.02%; zinc, 0.02%; iron, 0.01%; copper, 0.0025%; iodine, 0.0003%; selenium, 0.00003%; folic acid, 0.69 mg; choline, 386 mg; riboflavin, 6.61 mg; biotin, 0.03 mg; vitamin B_6, 1.38 mg; niacin, 27.56 mg; panthothenic acid, 6.61 mg; thiamine, 2.20 mg; menadione, 0.83 mg; vitamin B_{12}, 0.01 mg; vitamin E, 16.53 IU; vitamin D_3, 2,133 ICU; vitamin A, 7,716 IU

Hens were randomly assigned to receive 0, 0.1, 1, 4, or 8 mg of MGA/d in a balanced diet. From d 0 until 28, all groups were fed their respective diets and then were returned to a balanced layer diet containing no propylene glycol until d 44. Four hens on d 0 and 4 hens per treatment per day on d 1, 2, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, and 44 were euthanized. Hens were weighed, and tissues (liver, ovary, with and without large yellow follicles, and oviduct and its components the magnum and shell gland) were collected and weighed (g) when appropriate.

Statistical Analysis

Data for hen weight, ovary weight (both with and without the large yellow follicles), oviduct weight, magnum weight, shell gland weight, and liver weight were analyzed using the GLM procedure of SAS (SAS Inst., Cary, NC) to define regression models with day as a continuous variable and treatment (dosage of MGA) as a categorical variable (model variable = treatment |day| day). After the regression analysis, *t*-tests were used to make pairwise comparisons of the resultant slope coefficients. For a subset of data, ANOVA was used to determine differences in the weight of the ovary with large yellow follicles, oviduct weight, magnum weight, and shell gland weight among treatments on d 1, 28, and 44. $P < 0.05$ was considered significant.

RESULTS

There was no change in egg production throughout the 44 d of the experiment in groups receiving 0, 0.1, or 1 mg of MGA/d (Figure 1). However, in groups that received 4 or 8 mg of MGA/d, egg production decreased rapidly to 37 and 13%, respectively (Figure 1). Upon removal of MGA from the diet on d 28, there was a rapid increase in egg production in the groups receiving 4 and 8 mg of MGA/d (Figure 1).

Throughout the experiment hen body weight (1.65 ± 0.01 kg) remained similar among all 5 treatment groups and did not change throughout the duration of the experiment (Table 3). It is important to note that hens receiving MGA did not undergo a feather molt, which is often associated with inducing a period of rest.

No difference in the weight of the ovary without large yellow follicles was detected among treatments (9.2 ± 0.1 g). The mass of the large yellow follicles decreased in hens receiving 4 or 8 mg/d when compared with the groups receiving 0, 0.1, or 1 mg of MGA/d (Figure 2a and Tables 4 and 5). After removal of MGA, the mass of the large yellow follicles increased in the groups that received 4 or 8 mg of MGA/d and were similar to the mass of the groups on 0, 0.1, or 1 mg MGA/d by d 44 (Figure 2a, Tables 4 and 5).

Feeding hens a diet containing either 4 or 8 mg of MGA/d compared with those fed 0, 0.1, and 1 mg/d caused a decrease in oviduct weight (Figure 2b, Tables 4 and 5). After removal of MGA from the diet on d 28, the weight of the oviduct increased to meet controls by d 44 in the groups on 4 and 8 mg/d (Figure 2b, Tables 4 and 5). Groups receiving 4 or 8 mg of MGA/d had decreased magnum and shell gland weight compared with the groups on 0, 0.1, or 1 mg/d, and they maintained magnum and shell gland weight throughout the experiment (Figure 2, c and d; Tables 4 and 5). A steady increase in magnum and shell gland weight occurred in the groups on 4 and 8 mg/d after d 28 until reaching those of the 0, 0.1, and 1 mg of MGA/d groups (Figure 2, c and d; Tables 4 and 5). Liver weight (45.6 ± 0.5 g) was similar among all treatments throughout the experiment. Only one bird died during the experiment, which was a hen receiving 0 mg of MGA/d.

DISCUSSION

Incorporating MGA, an orally active progestin, into a balanced layer diet at a dosage of 4 or 8 mg/hen per d for 4 wk led to reversible regression of the reproductive tract. These treatments led to a regression of large yellow follicles on the ovary and a decrease in the weight of the oviduct, resulting in a dramatic decrease in egg production without a reduction in hen weight. Results of the current experiment, in which an orally active progestin was used as a treatment method, are similar to those observed previously, when treating with progesterone (Gabuten and Shaffner, 1954; Shaffner, 1954, 1955; Adams, 1955, 1956). Feeding progesterone dissolved in propylene glycol for 5 wk, at 110 or 220 mg/kg (11 or 22 mg/hen per d based on 0.1 kg of feed intake/d), resulted in a steady decline in egg production to 21 and 10%, respectively, within 28 d, without causing weight loss in the hens (Adams, 1956). Injection of 40 mg of progesterone caused a cessation of egg production within 2 d (Adams, 1955), whereas administration of 20 mg of slowly absorbed progesterone caused a cessation of egg production within 14 d (Shaffner, 1954), and an intramuscular injection of 0.5 or 1 mg of progesterone every day for 7 d practically eliminated egg production (Gabuten and Shaffner, 1954). In the current experiment, 4 or 8 mg/d of MGA resulted in a rapid decline in egg production, which is similar to previous research in which feeding progesterone led to a decrease but not complete cessation of lay.

There was no observed decrease in total hen body weight between the control hens and those receiving MGA treatment, even though there was an observed decrease in oviduct weight of those receiving 4 or 8 mg of MGA per hen/d compared with those groups receiving 0, 0.1, or 1.0 mg of MGA. This result may due to the fact that hens are maintained on a balanced layer diet throughout the experiment and hens maybe gaining body weight.

Alternative methods to induce molt thus far have been unsuccessful in at least one desired outcome: consistent postmolt performance, hen well-being, or practicality for the industry. To date, most alternatives are based on feeding diets with alterations in mineral content (i.e., low calcium, low sodium, or high zinc) or feeding a low nutrient density diet (i.e., wheat middling). Feeding a corn

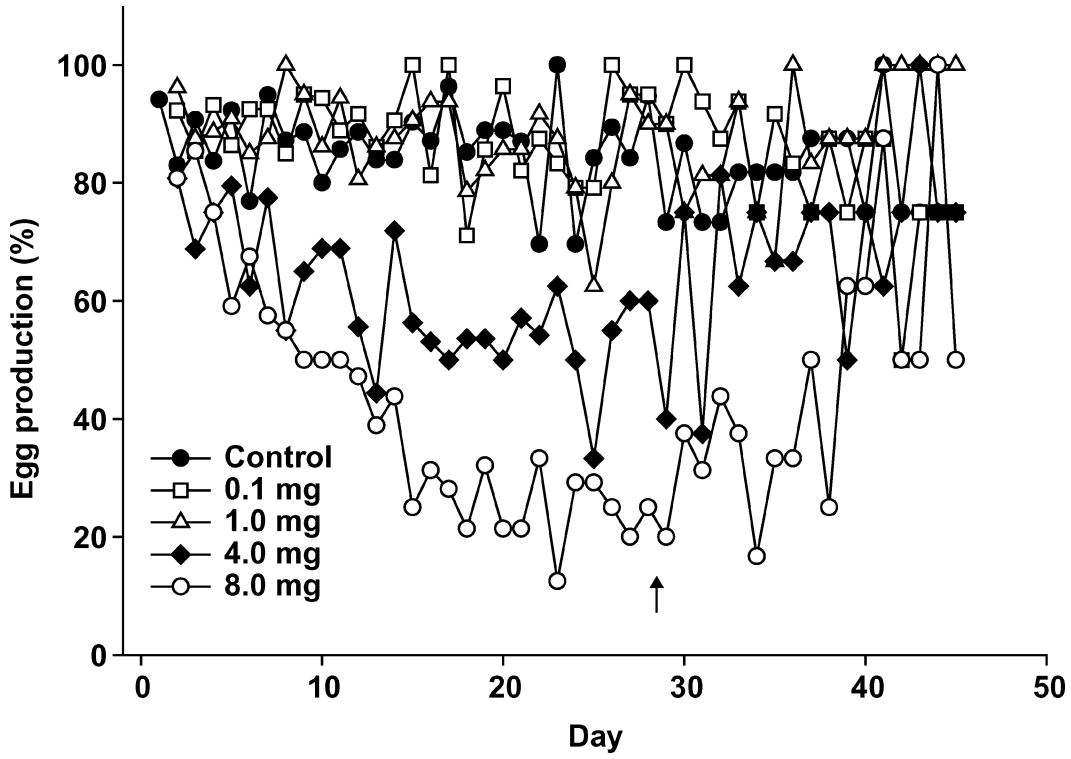

Figure 1. Daily egg production for hens fed 0, 0.1, 1, 4, and 8 mg of melengestrol acetate (MGA) per hen per day, beginning on d 0. The arrow indicates when MGA was removed from the feed on d 28.

and soybean based diet that contains less than 5% of the required daily dietary calcium (NRC, 1994) led to at least a 66% reduction in egg production within 2 wk and complete cessation after being on treatment of 4 wk. Egg production following the return to required calcium level varied from 30 to 100% of control production (Nevalainen, 1969; Douglas et al., 1972). Furthermore, low calcium diets were not effective in improving egg specific gravity (a measure of shell quality) posttreatment, caused paralysis in some hens, and increased mortality up to 20% compared with hens maintained on a diet meeting hen requirements (Douglas et al., 1972). Feeding a corn and soybean based diet that contained no added sodium (i.e., low sodium diet containing approximately 20% of the sodium requirement; NRC, 1994) resulted in cessation of lay within 3 wk. Upon return to a balanced sodium diet, egg production increased to control levels (Nesbeth et al., 1976a). Use of a low sodium diet for 42 d as an alternative to induce molt did result in increased egg weight and egg specific gravity above that of the control; however, feeding a low sodium diet led to a 59% decrease in feed intake that resulted in a 19% loss in hen body weight during the molt (Nesbeth et al., 1976b). Feeding a diet containing 150 times the daily recommended zinc content (NRC, 1994; in the form of zinc acetate or zinc oxide), eliminated production within 1 wk and decreased feed intake by at least 50% depending on the dietary zinc concentration (Shippee et al., 1979; Berry and Brake, 1987). There were no improvements in egg specific gravity, internal egg quality, or egg production for hens induced to molt by a high zinc diet compared with traditional feed withdrawal (Shippee et al., 1979).

Wheat middlings are a low energy and low protein feedstuff. Diets containing a substantial quantity of wheat middlings do not supply the nutrients needed by hens for egg production but provide bulk feedstuff to increase gut fill. A diet containing approximately 94% wheat middling reduced (i.e., 8% of production) or eliminated egg production within 8 to 28 d (Biggs et al., 2003, 2004). The wheat middling containing diet resulted in an immediate

Table 3. Hen body weight on d 1, 20, 28, 36, and 44 (mean ± SEM)

MGA[1] treatment (mg/hen per d)	Day 1	Day 20	Day 28	Day 36	Day 44
0	1.61 ± 0.10	1.79 ± 0.13	1.64 ± 0.09	1.59 ± 0.05	1.68 ± 0.13
0.1	1.61 ± 0.05	1.51 ± 0.05	1.65 ± 0.04	1.50 ± 0.07	1.59 ± 0.04
1.0	1.69 ± 0.03	1.68 ± 0.11	1.54 ± 0.06	1.55 ± 0.07	1.49 ± 0.05
4.0	1.78 ± 0.04	1.67 ± 0.04	1.62 ± 0.08	1.56 ± 0.07	1.58 ± 0.07
8.0	1.67 ± 0.07	1.57 ± 0.09	1.63 ± 0.05	1.50 ± 0.06	1.59 ± 0.14

[1]Melengestrol acetate.

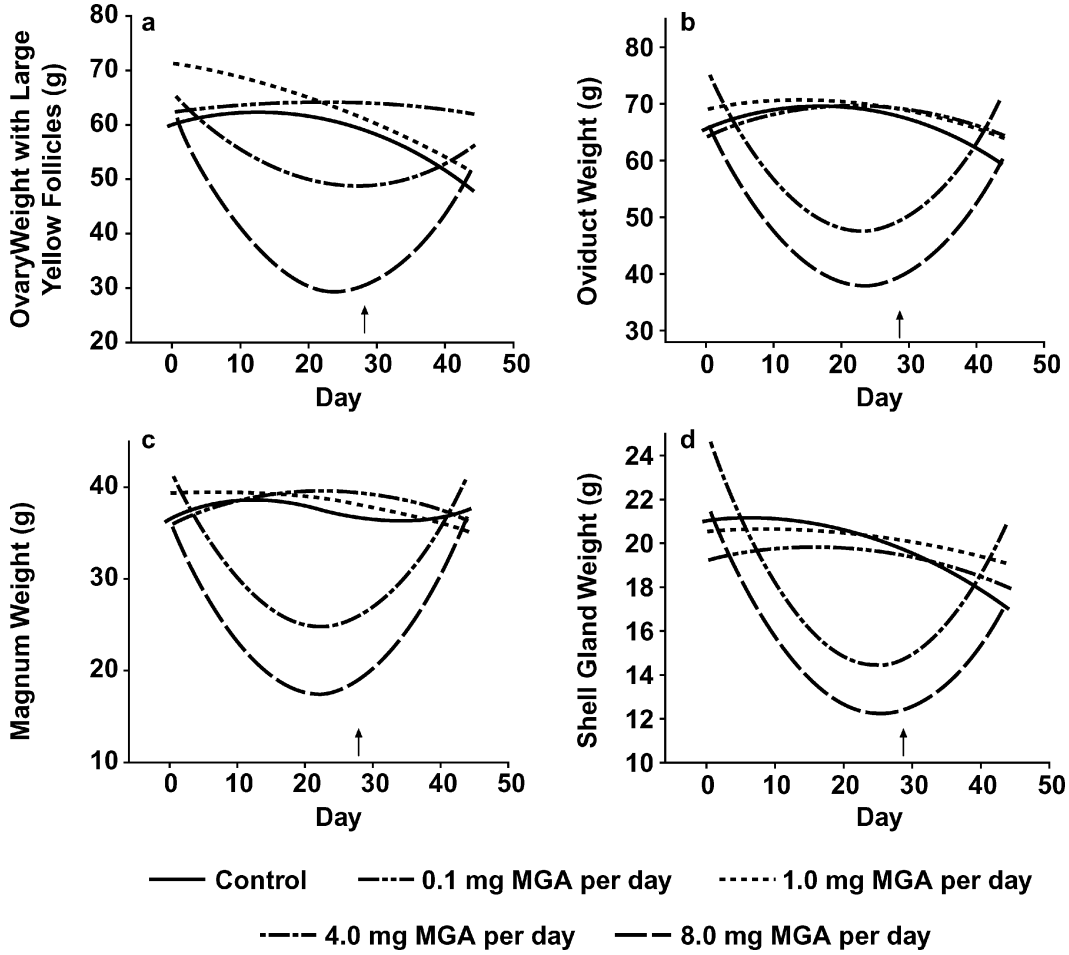

Figure 2. The weight of the a) ovary with large yellow follicles, b) oviduct, c) magnum, and d) shell gland for hens fed 0, 0.1, 1, 4, and 8 mg of melengestrol acetate (MGA) per hen per day, beginning on d 0. The linear and quadratic components of the regression lines for the groups fed 4 and 8 mg per hen/d differed from the group fed 0 mg per hen/d ($P < 0.05$). Ovary weight without large yellow follicles was not different among groups indicating that the reduction and recovery in weight in the 4 and 8 mg groups was a result of regression and recrudescence of the large yellow follicles. Arrow indicates when MGA was removed from the feed on d 28.

decrease in lay but did not result in increased egg production, improved internal egg quality (i.e., albumen height or egg weight), or improved egg specific gravity compared with those molted by feed withdrawal (Biggs et al., 2003, 2004). Hens consuming a wheat middling diet lost, on average, 13% of their initial body weight during treatment, which was due to a 30% reduction in feed intake (Biggs et al., 2003, 2004).

The large yellow follicles found on the ovary are supported by 2 gonadotropins, luteinizing hormone (LH) and follicle-stimulating hormone (FSH). These 2 gonadotropins are secreted from the anterior pituitary in response to gonadotropin-releasing hormone (GnRH) released from the hypothalamus. The GnRH release is regulated in a negative feedback loop by the steroids progesterone and estrogen. Disruption of this hypothalamic-hypophyseal-gonadal axis results in an interruption of egg production. It has been speculated that regression of the reproductive tract, which occurs during a molt, and the postmolt rejuvenation are both essential for the observed increase in postmolt performance (Brake and Thraxton, 1979). Alternative methods that can effectively alter the hypothalamic-hypophyseal-gonadal axis, causing reversible regression of the reproductive tract without extreme hen weight loss or other physiological insult to the hen, would be preferred compared with feed withdrawal or nutrient restriction to induce a molt. In the current experiment daily oral administration of 4 or 8 mg of MGA/d resulted in a decline in egg production (Figure 1) subsequent to regression of the large yellow follicles (Figure 2a) and the oviduct (Figure 2b, 2c and 2d). These results are similar to other studies in which the hypothalamic-hypophyseal-gonadal axis was altered by some antigonadotrophic hormone. Constant infusion of a GnRH agonist (which desensitizes the pituitary to GnRH) has been shown to cause a reduction in progesterone concentration and the weight of the ovary and oviduct leading to cessation of lay (Dickerman and Bahr, 1989). Injection with LH, FSH and LH with progesterone, or FSH with progesterone has been shown to interrupt or eliminate lay for at least 3 wk (Juhn and Harris, 1956). Enheptin, an antigonadotropin, suppresses the onset of lay (Pino and Hudson, 1953). Similar results are found when feeding or injecting progesterone, also an antigonadotropin (Gabuten and Shaf-

Table 4. The weight of the ovary including large yellow follicles, oviduct, magnum, and shell gland on d 1, 28, and 44 (mean ± SEM)

MGA[1] treatment (mg/hen per d)	Day 1	Day 28	Day 44
Ovary with follicles weight			
0	52.13 ± 2.39^{A}	56.88 ± 3.74^{AB}	47.95 ± 4.16^{AB}
0.1	60.45 ± 6.42^{AB}	61.30 ± 4.13^{AC}	62.48 ± 4.84^{A}
1.0	77.03 ± 7.92^{B}	54.15 ± 3.23^{ABC}	47.83 ± 1.50^{AB}
4.0	59.75 ± 5.07^{AB}	43.93 ± 11.17^{BD}	49.80 ± 6.52^{AB}
8.0	61.05 ± 3.41^{AB}	29.25 ± 11.21^{D}	39.15 ± 5.91^{B}
Oviduct weight			
0	62.20 ± 2.01^{A}	69.45 ± 3.36^{A}	58.13 ± 2.89^{A}
0.1	71.53 ± 5.91^{A}	66.80 ± 2.20^{A}	65.78 ± 2.21^{A}
1.0	68.20 ± 4.46^{A}	64.50 ± 1.51^{A}	63.90 ± 2.97^{A}
4.0	73.18 ± 2.51^{A}	48.15 ± 9.08^{B}	63.53 ± 4.68^{A}
8.0	71.20 ± 1.87^{A}	33.55 ± 10.18^{B}	51.18 ± 10.91^{A}
Magnum weight			
0	35.60 ± 2.34^{A}	37.70 ± 2.46^{A}	37.78 ± 1.08^{A}
0.1	39.90 ± 3.69^{A}	38.08 ± 2.58^{A}	36.68 ± 1.25^{A}
1.0	38.78 ± 2.55^{A}	34.93 ± 0.48^{A}	33.13 ± 3.56^{A}
4.0	40.00 ± 1.76^{A}	24.56 ± 6.53^{B}	35.50 ± 3.46^{A}
8.0	41.10 ± 1.23^{A}	17.28 ± 6.15^{B}	31.78 ± 7.14^{A}
Shell gland weight			
0	23.56 ± 1.53^{AB}	20.50 ± 0.79^{A}	15.63 ± 1.13^{A}
0.1	21.93 ± 1.59^{A}	17.38 ± 0.45^{AB}	17.90 ± 0.93^{A}
1.0	22.10 ± 1.72^{AB}	19.18 ± 0.23^{A}	19.03 ± 0.78^{A}
4.0	26.90 ± 0.72^{B}	14.08 ± 1.92^{BC}	18.88 ± 3.03^{A}
8.0	23.98 ± 1.57^{AB}	11.45 ± 2.95^{C}	14.38 ± 2.94^{A}

$^{A-D}$Means ± SEM with different superscripts differ within a day ($P < 0.05$).

[1]Melengestrol acetate.

fner, 1954; Shaffner, 1954; Adams, 1956). Interference with the hypothalamic-hypophyseal-gonadal axis by any means can result in a loss of gonadotropic support of the large yellow follicles resulting in a loss of steroidogenic support for the oviduct.

The physiological responses that occur during traditional molting (i.e., hen weight loss, feather molt, and complete cessation of lay) are used as indicators of molt effectiveness and are considered important to increase postmolt performance. However, the key to increasing

Table 5. Regression equations for the regression lines found in Figure 2 and the *P*-values for the pairwise comparisons of the highest order slope coefficient

MGA treatment (mg/hen per d)	Regression equation	*P*-value 0.1	1.0	4.0	8.0
Ovary with follicles					
0 mg	$-0.015x^2 + 0.38x + 59.51$	0.61	0.76	0.055	0.0002
0.1 mg	$-0.005x^2 + 0.22x + 61.87$		0.85	0.17	0.0017
1.0 mg	$-0.009x^2 + -0.10x + 70.61$			0.12	0.0009
4.0 mg	$0.021x^2 + -1.18x + 65.34$				0.072
8.0 mg	$0.055x^2 + -2.72x + 61.83$				
Oviduct					
0 mg	$-0.015x^2 + 0.50x + 65.08$	0.83	0.63	<0.0001	<0.0001
0.1 mg	$-0.012x^2 + 0.49x + 64.21$		0.79	<0.0001	<0.0001
1.0 mg	$-0.008x^2 + 0.26x + 68.86$			<0.0001	<0.0001
4.0 mg	$0.055x^2 + -2.54x + 76.60$				0.92
8.0 mg	$0.054x^2 + -2.52x + 67.19$				
Magnum					
0 mg	$-0.002x^2 + 0.07x + 36.87$	0.60	0.90	<0.0001	<0.0001
0.1 mg	$-0.007x^2 + 0.35x + 34.47$		0.70	<0.0001	<0.0001
1.0 mg	$-0.003x^2 + 0.04x + 39.20$			<0.0001	<0.0001
4.0 mg	$0.034x^2 + -1.56x + 42.23$				0.56
8.0 mg	$0.040x^2 + -1.77x + 36.51$				
Shell gland					
0 mg	$-0.003x^2 + 0.04x + 20.94$	0.93	0.72	<0.0001	0.0003
0.1 mg	$-0.003x^2 + 0.07x + 19.70$		0.79	<0.0001	0.0006
1.0 mg	$-0.002x^2 + 0.02x + 19.70$			0.0002	0.0016
4.0 mg	$0.018x^2 + -0.87x + 25.25$				0.59
8.0 mg	$0.015x^2 + -0.76x + 21.97$				

egg quality postmolt is regression and rejuvenation of the cells that line the reproductive tract (Brake and Thaxton, 1979). Traditional feed-withdrawal-induced molting and current alternative methods of inducing molt interfere with the hypothalamic-hypophyseal-gonadal axis by nutrient deprivation, whereas the method used in the current experiment uses a well-understood physiological mechanism to effectively shut down the hypothalamic-hypophyseal-gonadal axis, leading to regression and rejuvenation of the reproductive tract. Future experiments can be done to assess the effect of a greater MGA dose. Increasing the dose of MGA or altering other conditions, such as lighting, may decrease egg production below the observed 13% resulting in further regression of the reproductive tract.

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REFERENCES

Adams, J. L. 1955. Progesterone-induced unseasonable molt in single comb white leghorn pullets. Poult. Sci. 34:702–707.

Adams, J. L. 1956. A comparison of different methods of progesterone administration to the fowl in affecting egg production and molt. Poult. Sci. 35:323–326.

Berry, W. D. 2003. The physiology of induced molting. Poult. Sci. 82:971–980.

Berry, W. D., and J. Brake. 1987. Postmolt performance of laying hens molted by high dietary zinc, low dietary sodium, and fasting: egg production and eggshell quality. Poult. Sci. 66:218–226.

Biggs, P. E., M. W. Douglas, K. W. Koelkebeck, and C. M. Parsons. 2003. Evaluation of nonfeed removal methods for molting programs. Poult. Sci. 82:749–753.

Biggs, P. E., M. E. Persia, K. W. Koelkebeck, and C. M. Parsons. 2004. Further evaluation of nonfeed removal methods for molting programs. Poult. Sci. 83:745–752.

Brake, J., and P. Thaxton. 1979. Physiological changes in caged layers during a forced molt. Gross changes in organs. Poult. Sci. 58:707–716.

Dickerman, R. W., and J. M. Bahr. 1989. Molting induced by gonadotropin-releasing hormone agonist as a model for studying endocrine mechanisms of molting in laying hens. Poult. Sci. 68:1402–1408.

Douglas, C. R., R. H. Harms, and H. R. Wilson. 1972. The use of extremely low dietary calcium to alter the production pattern of laying hens. Poult. Sci. 51:2015–2020.

Gabuten, A. R., and C. S. Shaffner. 1954. A study of the physiological mechanisms affecting specific gravity of chicken eggs. Poult. Sci. 34:47–53.

Gast, R. K., and S. C. Ricket. 2003. Symposium: current and future prospects for induced molting in laying hens. Poult. Sci. 82:964.

Juhn, M., and P. C. Harris. 1956. Responses in molt and lay of fowl to progestins and gondaotrophins. Proc. Soc. Exp. Biol. Med. 92:709–711.

Lumijarvi, D. H., T. I. Koike, and F. W. Hill. 1966. Effects of sodium deficiency in the chick on water intake, fluid volumes, plasma electrolytes, and plasma osmolality. Poult. Sci. 45:1110–1101. (Abstr.)

National Research Council. 1994. Nutrient Recuirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.

Nevalainen, T. J. 1969. The effect of calcium-deficient diet on the reproductive organs of the hen. Poult. Sci. 48:653–659.

Nesbeth, W. G., C. R. Douglas, and R. H. Harms. 1976a. The potential use of dietary salt deficiency for the force resting of laying hens. Poult. Sci. 55:2375–2379.

Nesbeth, W. G., C. R. Douglas, and R. H. Harms. 1976b. response of laying hens to low salt diet. Poult. Sci. 55:2128–2133.

Pino, J. A., and C. B. Hudson. 1953. Duration of sexual retardation in S.C. white leghorn pullets and cockerels following enheptin (2-amino, 5-nitrothiazole) feeding. Poult. Sci. 32:650–655.

Siegel, H. S. 1961. Effect of level of dietary salt on the histology of the adrenal and kidney of young chickens. Poult. Sci. 40:1455–1456.

Shaffner, C. S. 1954. Feather papilla stimulation by progesterone. Science 120:345.

Shaffner, C. S. 1955. Progesterone induced molt. Poult. Sci. 34:840–842.

Shippee, R. L., P. E. Stake, U. Koehn, J. L. Lambert, and R. W. Simmons, III. 1979. High dietary zinc or magnesium as forced-resting agents for laying hens. Poult. Sci. 58:949–954.